

PROTOCOL

BIOACCUMULATION AND BIOCONCENTRATION SCREENING

Introduction

This protocol has been developed to support the bioaccumulation and bioconcentration evaluation that is conducted as part of the Ecological Constituent of Potential Concern (COPC) Selection Process. This protocol specifically addresses the screening conducted in Step D of the Ecological COPC Selection Process. The purpose of Step D is to identify constituents for which bioaccumulation or bioconcentration may be of concern. This is accomplished using this protocol to determine: (1) if the constituent exceeds an octanol/water partition coefficient (K_{ow}) threshold for surface water, (2) if the constituent exceeds a bioaccumulation factor (BAF) threshold for soil or sediment, or (3) if the constituent exceeds a bioconcentration factor (BCF) for surface water. If the K_{ow} , BAF, or BCF exceeds the screening threshold and its maximum concentration exceeds its two times average background concentration, the constituent is carried forward to Step E of the Ecological COPC Selection Process for further processing. Step E is also where radionuclides are first evaluated (including their relevant BAFs and BCFs); therefore, radionuclides are not included in this protocol.

Details

Screening Steps

This protocol segregates the bioaccumulation and bioconcentration screening process into two steps. Each step is presented below and results in a list of constituents associated with each step for which bioaccumulation or bioconcentration is of concern. The lists will be used in Step D of the Ecological COPC Selection Process.

Step 1: Octanol-Water Partition Coefficient (K_{ow}) Threshold Screening

Step 1 is used for organic constituents in surface water and is based on K_{ow} screening. A BCF may be estimated from a K_{ow} based on a mathematical conversion. It has been shown that the K_{ow} and BCF have a functional relationship in that the higher the K_{ow} , the higher the BCF. However, this functional relationship exists only within a specific range of K_{ow} values. Therefore, the K_{ow} rather than the BCF is used in this screening step. This step is restricted to organic constituents in surface water since K_{ow} values, as an indicator of surface water bioconcentration potential, have proven to be reasonably accurate for this class of compounds. Generally, bioaccumulation is most likely to occur with persistent and very hydrophobic chemicals; that is, those with log K_{ow} values from 5 to 8 (Hoffman et al. 1995). Screening for this step identifies the constituents in Table 1 with a K_{ow} between 5 to 8 as constituents likely to bioaccumulate or bioconcentrate.

The Step 1 evaluation identifies the following constituents as likely to bioaccumulate or bioconcentrate:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b and k)fluoranthene
- Benzo(g,h,i)perylene
- Bis(2-ethylhexyl)phthalate
- Chrysene
- Dibenzo(a,h)anthracene
- Di-n-butylphthalate
- Di-n-octylphthalate
- Fluoranthene
- Indeno(1,2,3-c,d)pyrene
- Pyrene
- Aroclors
-
- alpha-Chlordane
- gamma-Chlordane
- 4,4'-DDD
- 4,4'-DDE
- 4,4'-DDT
- Dioxins
- Endrin
- Heptachlor epoxide

Step 2: BAF and BCF Threshold Screening

Step 2 is based on BAF and BCF threshold screening. Constituent-specific BCFs and BAFs are listed in Table 1 and were obtained from the literature where possible (HAZWWRAP 1994). A default value of 1 was used for BCFs and BAFs when no published literature value was available. In general, literature references pertaining to BAF or BCF thresholds refer to high BAF and BCF values as those from 300 to 1000. Calabrese and Baldwin (1993) refer to the use of safety factors that may be applied to such thresholds. Safety factors may be used to add conservatism to thresholds which is an important consideration when dealing with early screening of constituents. Therefore, a two-fold safety factor is being applied to the 1000 upper threshold to produce a screening threshold of 10. The Step 2 screening, based on a threshold of 10, is applied to identify constituents with BAFs for soil or sediment or BCFs for inorganics in surface water greater than 10 as constituents for which bioaccumulation or bioconcentration is of concern. Table 1 includes BAFs and BCFs for groups of receptors that are likely to be evaluated during the risk assessment process including plants, invertebrates, mammals, and fish.

The Step 2 evaluation identifies the following constituents as likely to bioaccumulate or bioconcentrate for surface water:

- Aluminum
- Arsenic
- Cadmium
- Chromium
- Cobalt
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Zinc

The Step 2 evaluation identifies the following constituents as likely to bioaccumulate or bioconcentrate for soil or sediment:

- Cadmium
- Mercury
- Di-n-octylphthalate

References

Calabrese, E. J. and L. A. Baldwin. 1993. *Performing Ecological Risk Assessments*. Lewis Publishers, Chelsea, MI.

Hoffman, D.J., B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. 1995. *Handbook of Ecotoxicology*. Lersi Publishers, Boca Raton, FL.

HAZWRAP. 1994. *Loring Air Force Base Ecological Risk Methodology*. Martin Marietta Energy Systems, Inc. Draft.

Table 1. Biouptake Factors

Constituent	Log K_{ow}	Soil-to-Plant		Soil-to-Animal*	Animal-to-Animal	Soil-to-Tissue	Water-to-Fish
		SP _v	SP _r	BAF _{inv}	BAF _{mamm}	ST	BCF
Inorganics							
Aluminum		8.00E-04 a	1.30E-04 a	7.50E-02 b	7.50E-02 b	1.00E+00 c	1.00E+01 b
Antimony		4.00E-02 a	6.00E-03 a	5.00E-02 b	5.00E-02 b	1.00E+00 c	1.00E+00 b
Arsenic		8.00E-03 a	1.20E-03 a	6.60E-03 b	1.00E-01 b	1.00E+00 c	2.80E+02 b
Barium		3.00E-02 b	3.00E-02 b	7.50E-03 b	7.50E-03 b	1.00E+00 c	4.00E+00 b
Beryllium		2.00E-03 b	2.00E-03 b	5.00E-02 b	5.00E-02 b	1.00E+00 c	2.00E+00 b
Boron		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Cadmium		1.10E-01 a	3.00E-02 a	1.10E+01 b	2.80E-02 b	1.00E+00 c	5.00E+01 b
Calcium		7.00E-01 a	7.00E-02 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Chromium		1.50E-03 a	9.00E-04 a	1.60E-01 b	2.80E-01 b	1.00E+00 c	2.00E+02 b
Cobalt		4.00E-03 b	4.00E-03 b	1.00E+00 b	1.00E+00 b	1.00E+00 c	3.00E+02 b
Copper		8.00E-02 a	5.00E-02 a	1.60E-01 b	5.00E-01 b	1.00E+00 c	2.10E+02 b
Cyanide		1.00E+00 b	1.00E+00 b	0.00E+00 b	0.00E+00 b	1.00E+00 c	0.00E+00 b
Iron		8.00E-04 a	2.00E-04 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Lead		9.00E-03 a	1.80E-03 a	see note d	1.50E-02 b	1.00E+00 c	3.00E+02 b
Magnesium		2.00E-01 a	1.10E-01 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Manganese		5.00E-02 a	1.00E-02 a	2.00E-02 b	2.00E-02 b	1.00E+00 c	4.00E+02 b
Mercury		1.80E-01 a	4.00E-02 a	3.40E-01 b	1.30E+01 b	1.00E+00 c	6.30E+04 b
Nickel		1.20E-02 b	1.20E-02 b	2.30E-01 b	3.00E-01 b	1.00E+00 c	1.00E+02 b
Potassium		2.00E-01 a	1.10E-01 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Selenium		5.00E-03 b	5.00E-03 b	7.60E-01 b	7.50E-01 b	1.00E+00 c	8.00E+00 b
Silver		8.00E-02 a	2.00E-02 a	1.50E-01 b	1.50E-01 b	1.00E+00 c	2.00E+00 b
Sodium		1.50E-02 a	1.10E-02 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Thallium		8.00E-04 a	8.00E-05 a	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Vanadium		1.10E-03 a	6.00E-04 a	1.30E-01 b	1.30E-01 b	1.00E+00 c	1.00E-02 b
Zinc		3.00E-01 a	1.80E-01 a	1.80E+00 b	5.00E+00 b	1.00E+00 c	1.00E+03 b
Organics							
Acenaphthene	3.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-02 b	1.00E+00 c	3.90E+02 b
Acenaphthylene	4.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-02 b	1.00E+00 c	6.90E+02 b
Acetone	-24	2.00E-02 b	2.00E-02 b	5.00E-02 b	8.70E-07 b	1.00E+00 c	2.00E-01 b
Anthracene	4.5	2.00E-02 b	2.00E-02 b	5.00E-02 b	4.80E-02 b	1.00E+00 c	1.40E+03 b
Benzene	2.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-04 b	1.00E+00 c	3.20E+01 b
Benzo(a)anthracene	5.7	3.90E-03 b	3.90E-03 b	5.00E-02 b	7.60E-01 b	1.00E+00 c	1.30E+04 b
Benzo(a)pyrene	6.0	2.60E-03 b	2.60E-03 b	5.00E-02 b	1.50E+00 b	1.00E+00 c	3.00E+01 b
Benzo(b and k)fluoranthene	6.1	2.30E-03 b	2.30E-03 b	5.00E-02 b	1.90E+00 b	1.00E+00 c	2.60E+04 b
Benzo(g,h,i)perylene	6.6	1.20E-03 b	1.20E-03 b	5.00E-02 b	6.00E+00 b	1.00E+00 c	6.50E+04 b
Benzo(a)pyrene	6	2.60E-03 b	2.60E-03 b	5.00E-02 b	1.50E+00 b	1.00E+00 c	3.00E+01 b
Bis(2-ethylhexyl)phthalate	5.1	8.70E-03 b	8.70E-03 b	5.00E-02 b	1.90E-01 b	1.00E+00 c	3.10E+02 b

Table 1. Biouptake Factors (continued)

Constituent	Log <i>K</i>_{ow}	Soil-to-Plant		Soil-to- Animal*	Animal-to- Animal	Soil-to- Tissue	Water-to- Fish
		SP_v	SP_r	BAF_{inv}	BAF_{mamm}	ST	BCF
Bromomethane		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
2-Butanone		2.00E-02 b	2.00E-02 b	5.00E-02 b	2.90E-06 b	1.00E+00 c	6.00E-01 b
Butylbenzylphthalate	4.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-01 b	1.00E+00 c	6.60E+02 b
Carbon disulfide		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Carbon tetrachloride		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Carbazole	3.8	2.00E-02 b	2.00E-02 b	5.00E-02 b	8.70E-03 b	1.00E+00 c	3.70E+02 b
4-Chloroaniline	1.8	2.00E-02 b	2.00E-02 b	5.00E-02 b	9.50E-05 b	1.00E+00 c	1.10E+01 b
Chlorobenzene	2.8	2.00E-02 b	2.00E-02 b	5.00E-02 b	9.50E-04 b	1.00E+00 c	4.50E+02 b
Chloroform	2	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.50E-04 b	1.00E+00 c	6.00E+00 b
4-Chloro-3-methylphenol	3.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-03 b	1.00E+00 c	1.10E+02 b
Chrysene	5.7	3.90E-03 b	3.90E-03 b	5.00E-02 b	7.60E-01 b	1.00E+00 c	1.30E+04 b
Dibenzo(a,h)anthracene	6.5	1.40E-03 b	1.40E-03 b	5.00E-02 b	4.80E+00 b	1.00E+00 c	5.40E+04 b
Dibenzofuran	4.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-02 b	1.00E+00 c	6.90E+02 b
1,2-Dichloroethane	1.5	2.00E-02 b	2.00E-02 b	5.00E-02 b	6.00E-04 b	1.00E+00 c	8.00E+00 b
1,2-Dichloroethene	2	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.50E-04 b	1.00E+00 c	8.60E-01 b
Diethylphthalate	3.2	2.00E-02 b	2.00E-02 b	5.00E-02 b	2.40E-03 b	1.00E+00 c	1.20E+02 b
Di-n-butylphthalate	5.2	7.60E-03 b	7.60E-03 b	5.00E-02 b	2.40E-01 b	1.00E+00 c	5.10E+03 b
Di-n-octylphthalate	9.2	3.70E-05 b	3.70E-05 b	5.00E-02 b	2.40E+03 b	1.00E+00 c	9.30E+03 b
2,6,-Dinitrotoluene	2.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-04 b	1.00E+00 c	2.60E+01 b
Ethylbenzene	3.2	2.00E-02 b	2.00E-02 b	5.00E-02 b	2.40E-03 b	1.00E+00 c	2.90E+02 b
Fluoranthene	5.0	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.30E-01 b	1.00E+00 c	3.20E+03 b
Fluorene	4.2	2.00E-02 b	2.00E-02 b	5.00E-02 b	2.40E-02 b	1.00E+00 c	8.30E+02 b
2-Hexanone		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Indeno(1,2,3-c,d)pyrene	6.6	1.20E-03 b	1.20E-03 b	5.00E-02 b	6.00E+00 b	1.00E+00 c	6.50E+04 b
Methylene chloride	1.3	2.00E-02 b	2.00E-02 b	5.00E-02 b	3.00E-05 b	1.00E+00 c	4.00E+00 b
Methyl Ethyl Ketone		2.00E-02 b	2.00E-02 b	5.00E-02 b	2.90E-06 b	1.00E+00 c	6.00E-01 b
4-Methyl-2-pentanone		2.00E-02 b	2.00E-02 b	5.00E-02 b	2.40E-05 b	1.00E+00 c	6.00E+00 b
2-Methylnaphthalene	1.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-08 b	1.00E+00 c	4.30E+02 b
2-Methylphenol	2.0	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.50E-04 b	1.00E+00 c	1.50E+01 b
2-Methylphenol	2.0	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.50E-04 b	1.00E+00 c	1.50E+01 b
4-Methylphenol	1.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-04 b	1.00E+00 c	1.30E+01 b
Naphthalene	3.6	2.00E-02 b	2.00E-02 b	5.00E-02 b	6.00E-03 b	1.00E+00 c	4.30E+02 b
3-Nitroaniline		2.00E-02 b	2.00E-02 b	5.00E-02 b	3.80E-05 b	1.00E+00 c	5.10E+00 b
4-Nitroaniline		2.00E-02 b	2.00E-02 b	5.00E-02 b	3.80E-05 b	1.00E+00 c	5.10E+00 b
Nitrobenzene	1.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-04 b	1.00E+00 c	1.30E+01 b
2-Nitrophenol	1.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-04 b	1.00E+00 c	1.30E+01 b
4-Nitrophenol	1.9	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.20E-04 b	1.00E+00 c	1.30E+01 b
N-							
Nitrosodiphenylamine	3.1	2.00E-02 b	2.00E-02 b	5.00E-02 b	1.90E-03 b	1.00E+00 c	8.10E+01 b
Phenanthrene	4.5	2.00E-02 b	2.00E-02 b	5.00E-02 b	4.80E-02 b	1.00E+00 c	1.40E+03 b
Phenol	1.5	2.00E-02 b	2.00E-02 b	5.00E-02 b	4.80E-05 b	1.00E+00 c	7.80E+02 b

Table 1. Biouptake Factors (continued)

Constituent	Log <i>K</i>_{ow}	Soil-to-Plant		Soil-to- Animal*	Animal-to- Animal	Soil-to- Tissue	Water-to- Fish
		SP_v	SP_r	BAF_{inv}	BAF_{mamm}	ST	BCF
Pyrene	5.3	6.70E-03 b	6.70E-03 b	5.00E-02 b	3.00E-01 b	1.00E+00 c	6.10E+03 b
Styrene		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
1,1,2,2-Tetrachloroethane	2.6	2.00E-02 b	2.00E-02 b	5.00E-02 b	6.00E-04 b	1.00E+00 c	8.00E+00 b
Tetrachloroethene	3.4	2.00E-02 b	2.00E-02 b	5.00E-02 b	3.80E-03 b	1.00E+00 c	4.40E+01 b
Toluene	2.7	2.00E-02 b	2.00E-02 b	5.00E-02 b	7.60E-04 b	1.00E+00 c	8.30E+01 b
1,1,1-Trichloroethane		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Trichloroethene	2.4	2.00E-02 b	2.00E-02 b	5.00E-02 b	3.80E-04 b	1.00E+00 c	1.70E+01 b
2,4,6-Trichlorophenol	3.7	2.00E-02 b	2.00E-02 b	5.00E-02 b	7.60E-03 b	1.00E+00 c	3.30E+02 b
Vinyl chloride		1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c	1.00E+00 c
Xylenes, total	3.2	2.00E-02 b	2.00E-02 b	5.00E-02 b	2.40E-03 b	1.00E+00 c	1.70E+01 b
Pesticides/PCBs							
Aldrin	3.0	2.00E-02 b	2.00E-02 b	5.60E-01 b	2.90E+00 b	1.00E+00 c	1.10E+04 b
Aroclor-1254	6.0	3.80E-01 b	3.80E-01 b	5.80E+00 b	2.90E+00 b	1.00E+00 c	1.00E+07 b
Aroclor-1260	7.1	3.80E-01 b	3.80E-01 b	5.80E+00 b	2.90E+00 b	1.00E+00 c	1.00E+07 b
alpha-BHC	3.8	2.00E-02 b	2.00E-02 b	2.60E+00 b	2.90E+00 b	1.00E+00 c	7.10E+02 b
beta-BHC	3.8	2.00E-02 b	2.00E-02 b	2.60E+00 b	2.90E+00 b	1.00E+00 c	7.20E+02 b
delta-BHC	4.1	2.00E-02 b	2.00E-02 b	2.60E+00 b	2.90E+00 b	1.00E+00 c	6.90E+02 b
gamma-BHC (Lindane)	4.1	2.00E-02 b	2.00E-02 b	2.60E+00 b	2.90E+00 b	1.00E+00 c	1.00E+03 b
-Chlordane	5.5	5.10E-03 b	5.10E-03 b	1.60E+00 b	2.90E+00 b	1.00E+00 c	1.40E+06 b
gamma-Chlordane	5.5	5.10E-03 b	5.10E-03 b	1.60E+00 b	2.90E+00 b	1.00E+00 c	7.60E+04 b
4,4'-DDD	6.0	1.30E-03 b	1.30E-03 b	3.30E+00 b	2.95E+00 b	1.00E+00 c	1.75E+05 b
4,4'-DDE	5.7	2.00E-03 b	2.00E-03 b	1.70E+00 b	2.90E+00 b	1.00E+00 c	1.84E+07 b
4,4'-DDT	6.4	7.70E-04 b	7.70E-04 b	5.70E-01 b	2.90E+00 b	1.00E+00 c	3.40E+04 b
Dieldrin	4.6	2.00E-02 b	2.00E-02 b	5.50E+00 b	2.90E+00 b	1.00E+00 c	1.40E+04 b
Dioxins	-	3.80E-01 e	3.80E-01 e	5.80E+00 e	2.90E+00 e	1.00E+00 c	1.00E+07 e
Endosulfan I	3.6	2.00E-02 b	2.00E-02 b	5.50E+00 b	2.90E+00 b	1.00E+00 c	2.80E+02 b
Endosulfan II	3.6	2.00E-02 b	2.00E-02 b	5.50E+00 b	2.90E+00 b	1.00E+00 c	2.80E+02 b
Endosulfan sulfate	3.1	2.00E-02 b	2.00E-02 b	5.50E+00 b	2.90E+00 b	1.00E+00 c	1.10E+02 b
Endrin	5.6	4.50E-03 b	4.50E-03 b	1.90E+00 b	2.90E+00 b	1.00E+00 c	2.60E+03 b
Endrin aldehyde	3.1	2.00E-02 b	2.00E-02 b	1.90E+00 b	2.90E+00 b	1.00E+00 c	1.20E+02 b
Endrin ketone	3.1	2.00E-02 b	2.00E-02 b	1.90E+00 b	2.90E+00 b	1.00E+00 c	1.20E+02 b
Heptachlor	4.3	2.00E-02 b	2.00E-02 b	1.00E+00 b	2.90E+00 b	1.00E+00 c	1.40E+04 b
Heptachlor epoxide	5.4	5.90E-03 b	5.90E-03 b	1.00E+00 b	2.90E+00 b	1.00E+00 c	1.40E+04 b
Methoxychlor	4.8	2.00E-02 b	2.00E-02 b	5.70E-01 b	2.90E+00 b	1.00E+00 c	8.30E+03 b

Table 1. Biouptake Factors (continued)

SP = Soil-to-Plant Transfer; v = vegetative parts, r = reproductive parts

BAF = Bioaccumulation Factor; inv = invertebrate (unitless), mamm = mammal (d/kg)

* BAF_{inv} also used for sediment-to-invertebrate transfer

BCF = Bioconcentration factor for transfer from water to fish and other aquatic biota (L/kg)

a Baes et al. (1984), SP converted to wet weight assuming 80% water by weight

b HAZWRAP (1994)

c Default value

d Calcium-dependent: BAF-Pb = C_{Worm-Pb}/C_{Soil-Pb}, where C_{Worm-Pb} = $14.45 \times 10^{0.916 \log(C_{Soil-Pb})/10}$
 $0.326\log(C_{Soil-Ca})$ from HAZWRAP (1994)

e Aroclor-1254 used as a surrogate.